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Lee

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(54) **SEMICONDUCTOR MEMORY DEVICE**

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(57) **ABSTRACT**

A semiconductor memory device includes at least one cell string to include a plurality of dummy memory cells and a plurality of memory cells connected in series between the plurality of dummy memory cells; and the peripheral circuit to control the at least one cell string so that a first type of data represented by a first number of bits is stored in at least one of the dummy memory cells and a second type of data represented by a second number of bits, the second number smaller than the first number, is stored in at least two of the plurality of memory cells.

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(58) **Field of Classification Search**

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20 Claims, 10 Drawing Sheets

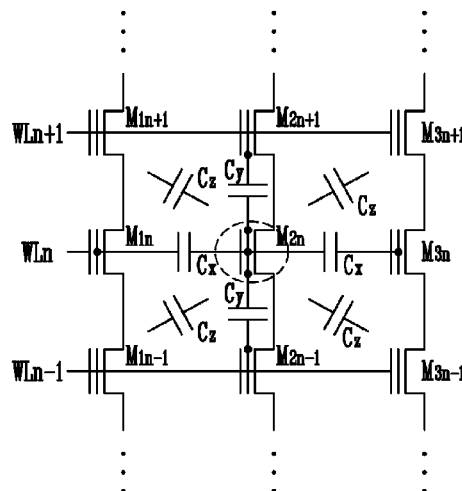


FIG. 1

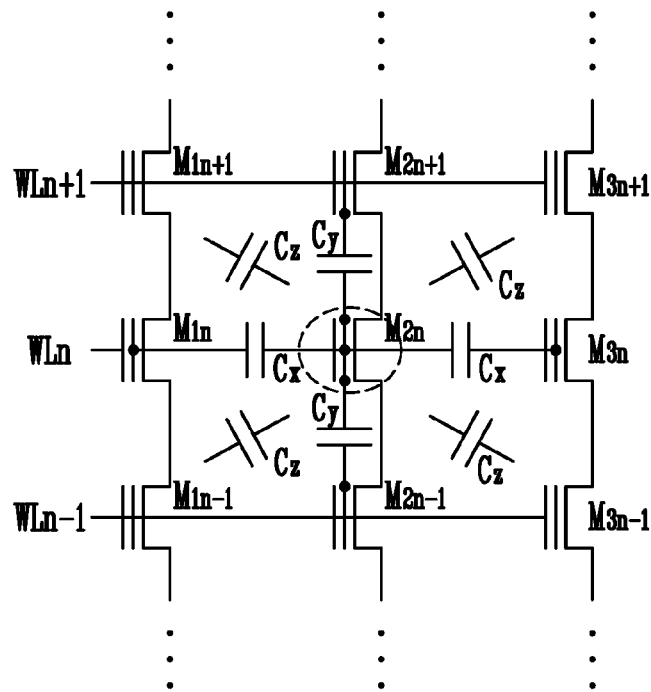


FIG. 2

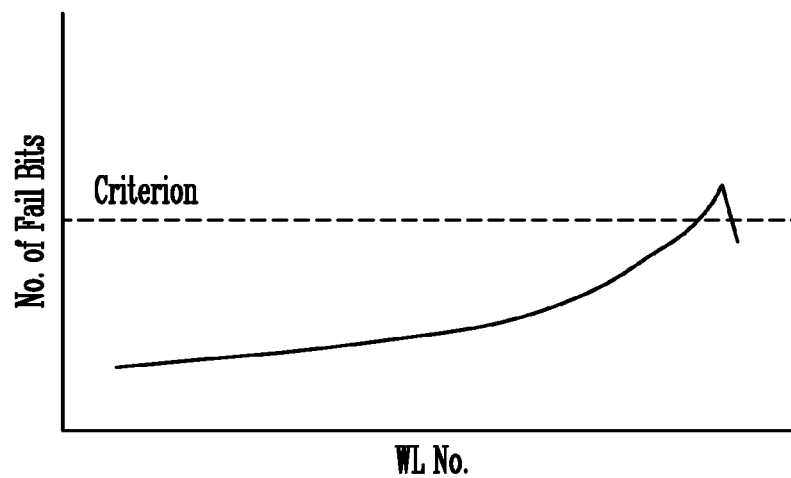


FIG. 3

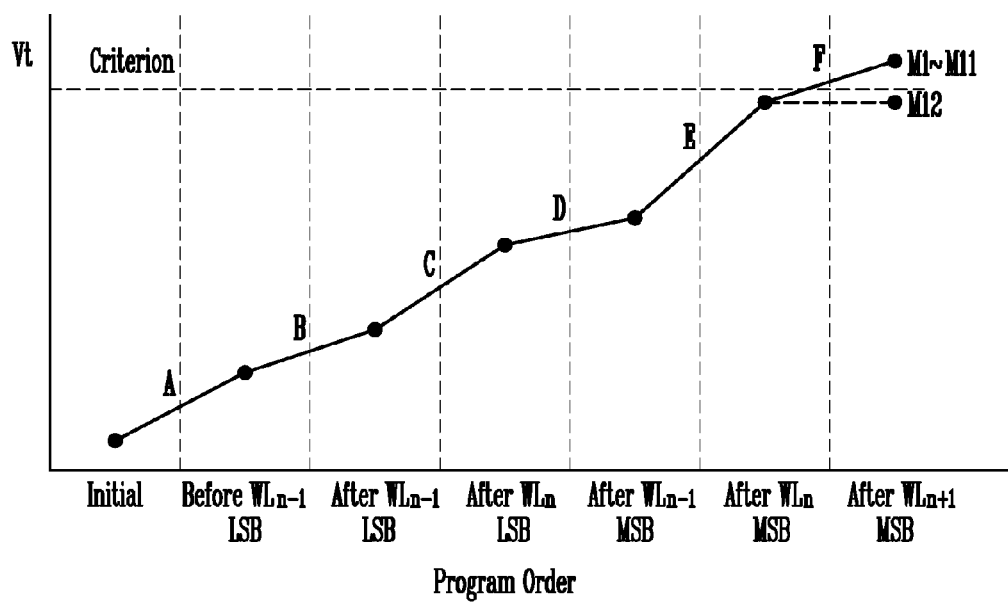


FIG. 4

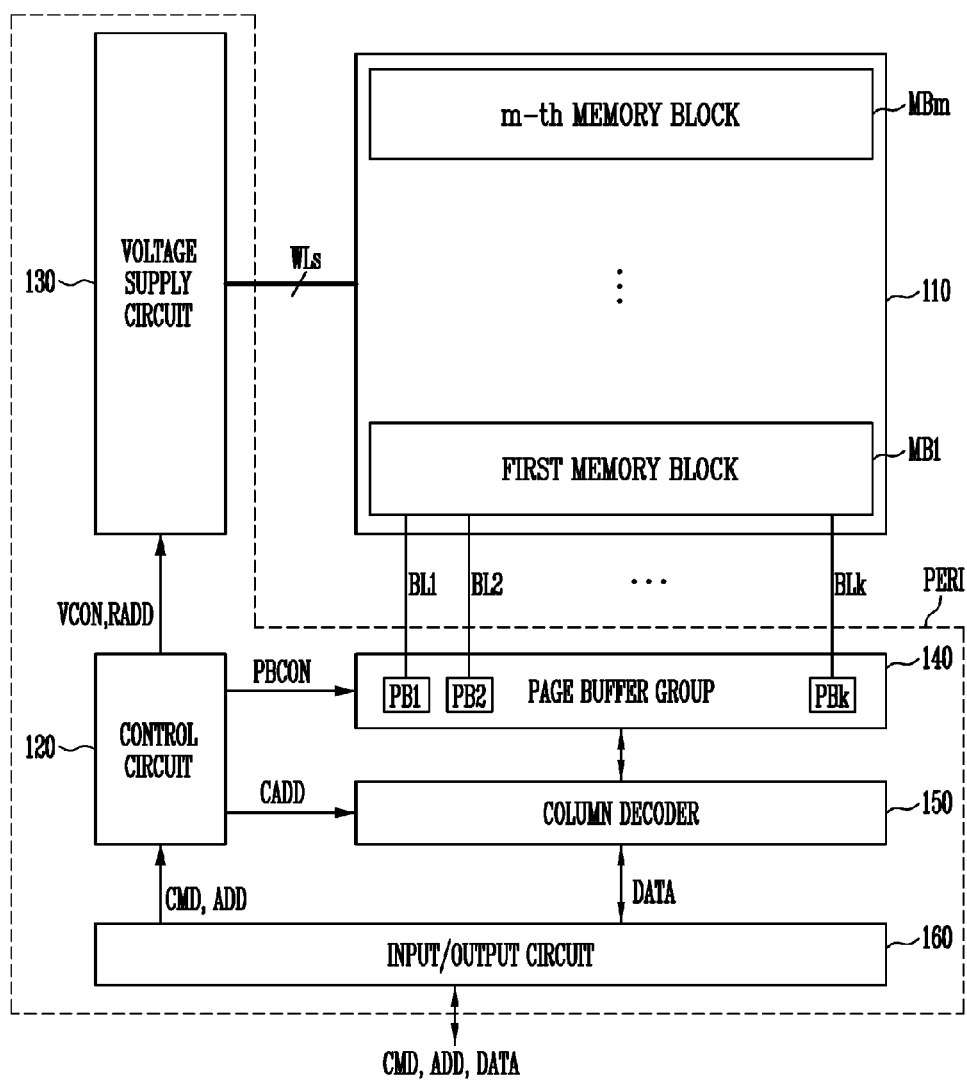
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FIG. 5

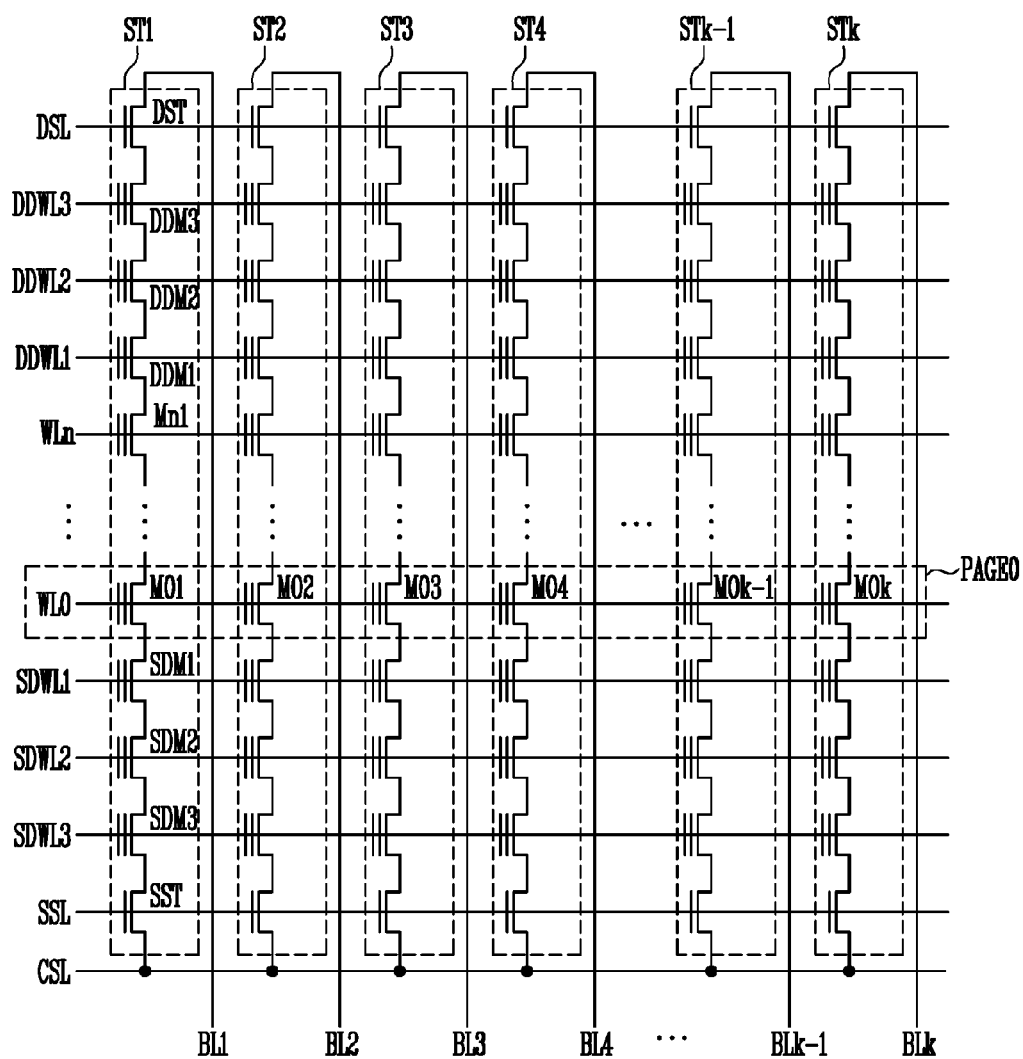


FIG. 6

SST	SDM3	SDM2	SDM1	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	DDM1	DDM2	DDM3	DST
X				2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	1 bit	2 bit	1 bit	2 bit			X

FIG. 7

SST	SDM3	SDM2	SDM1	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	DDM1	DDM2	DDM3	DST
X				2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit			X

FIG. 8

SST	SDM3	SDM2	SDM1	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	DDM1	DDM2	DDM3	DST
X				2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit	2 bit			X

FIG. 9

SST	SDM3	SDM2	SDM1	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	DDM1	DDM2	DDM3	DST
X			2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	1 bit	2 bit	1 bit	2 bit				X

FIG. 10

SST	SDM3	SDM2	SDM1	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	DDM1	DDM2	DDM3	DST
X			2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit				X

FIG. 11

SST	SDM3	SDM2	SDM1	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	DDM1	DDM2	DDM3	DST
X			2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit	2 bit				X

FIG. 12

SST	SDM3	SDM2	SDM1	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	DDM1	DDM2	DDM3	DST
X			2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	1 bit	2 bit	1 bit	2 bit	1 bit	2 bit	1 bit	2 bit			X

FIG. 13

SST	SDM3	SDM2	SDM1	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	DDM1	DDM2	DDM3	DST
X			2 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit			X

FIG. 14

SST	SDM3	SDM2	SDM1	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	DDM1	DDM2	DDM3	DST
X			2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit	2 bit			X

FIG. 15

SST	SDM3	SDM2	SDM1	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	DDM1	DDM2	DDM3	DST
X				2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	1 bit	2 bit	1 bit	2 bit	1 bit	2 bit	1 bit	2 bit		X

FIG. 16

SST	SDM3	SDM2	SDM1	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	DDM1	DDM2	DDM3	DST
X				2 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit		X

FIG. 17

SST	SDM3	SDM2	SDM1	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	DDM1	DDM2	DDM3	DST
X				2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit	2 bit		X

FIG. 18

SST	SDM3	SDM2	SDM1	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	DDM1	DDM2	DDM3	DST
X		2 bit	2 bit	2 bit	2 bit	2 bit	2 bit	1 bit	2 bit	1 bit	2 bit	1 bit	2 bit	1 bit	2 bit				X

FIG. 19

SST	SDM3	SDM2	SDM1	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	DDM1	DDM2	DDM3	DST
X		2 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit				X

FIG. 20

SST	SDM3	SDM2	SDM1	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	DDM1	DDM2	DDM3	DST
X		2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit	2 bit	1 bit	2 bit	2 bit				X

FIG. 21

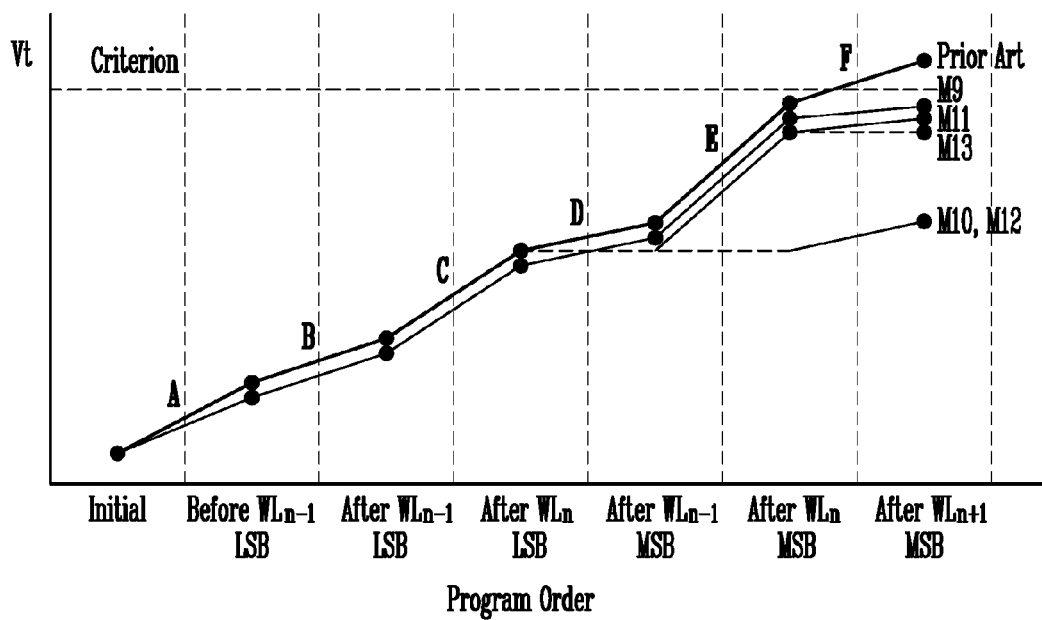


FIG. 22

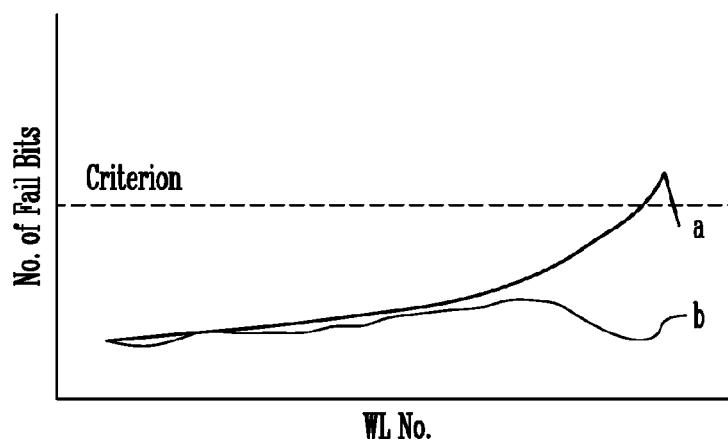


FIG. 23

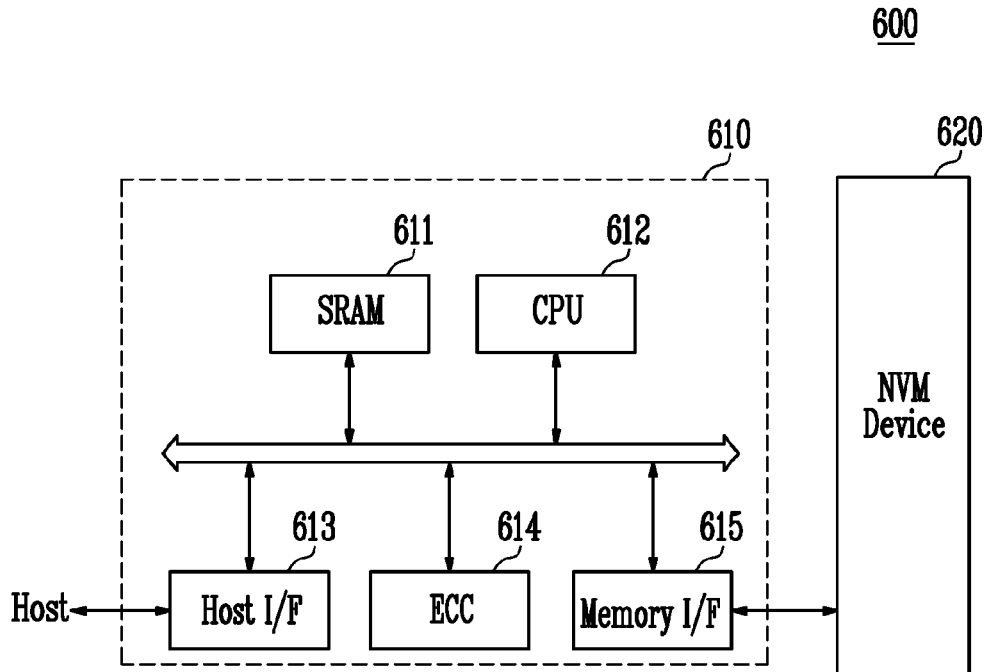


FIG. 24

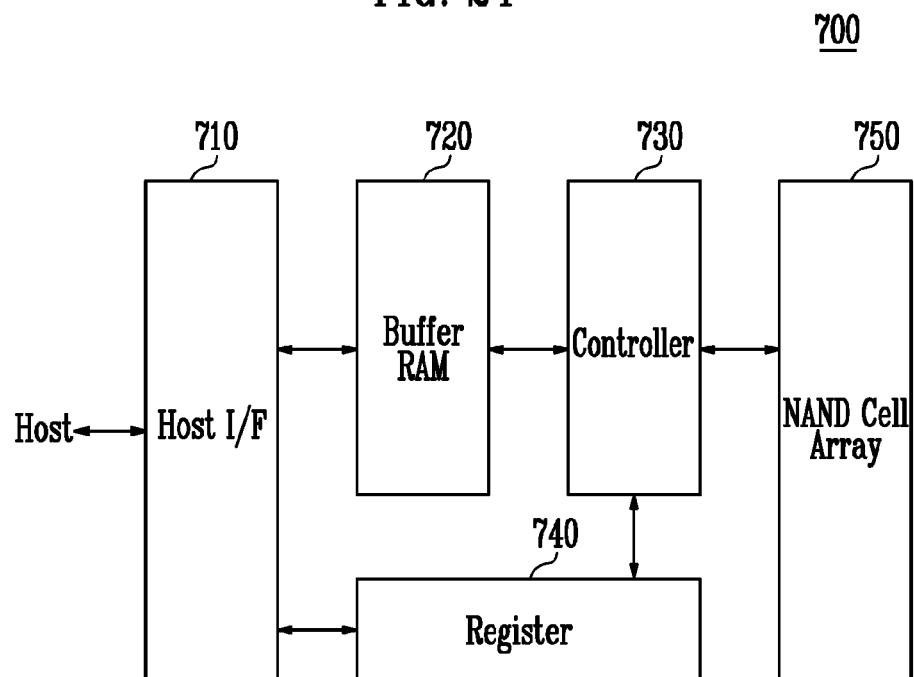
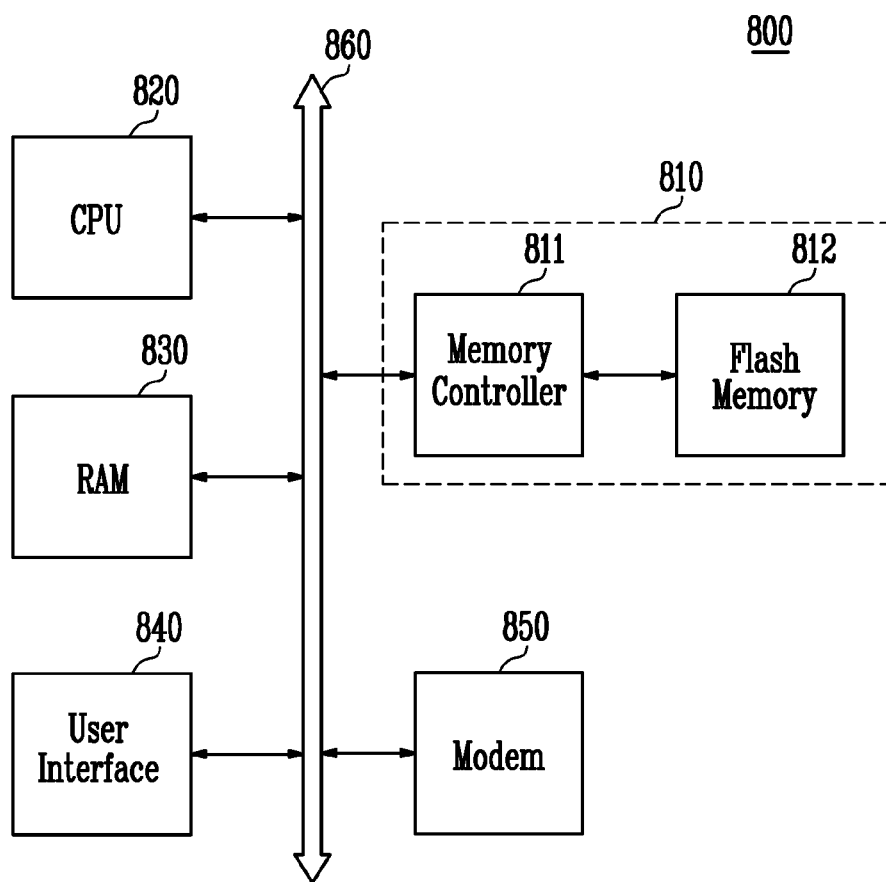


FIG. 25



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SEMICONDUCTOR MEMORY DEVICE**CROSS-REFERENCE TO RELATED APPLICATION**

The present application claims priority to Korean patent application number 10-2013-0095910 filed on Aug. 13, 2013, in the Korean Intellectual Property Office. The disclosure of the above-listed application is hereby incorporated by reference herein in their entirety.

FIELD

The present disclosure relates to an electronic device and, more particularly, to a semiconductor memory device.

BACKGROUND

The statements in this section merely provide background information related to the present disclosure and do not constitute prior art.

A semiconductor memory device is classified into a volatile memory device and a non-volatile memory device.

The volatile memory device performs a high speed data read and write operation, but the stored data is lost when the power is cut off. The non-volatile memory device operates at relatively lower write and read speeds, but the stored data is preserved even when the power is cut off. Therefore, the non-volatile memory device is used to store data that is to be maintained regardless of power supply. Examples of the non-volatile memory device include a read only memory (ROM) device, a programmable ROM (PROM) device, an electrically programmable ROM (EPROM) device, an electrically erasable and programmable ROM (EEPROM) device, a flash memory device, a phase-change RAM (PRAM) device, a magnetic RAM (MRAM) device, a resistive RAM (RRAM) device, a ferroelectric RAM (FRAM) device, or the like. The Flash memory device is typically divided into a NOR device and a NAND device.

The flash memory device enjoys the advantages of both RAM and ROM devices. For example, the flash memory device can be freely programmed and erased similar to the RAM device. Similar to the ROM device, the flash memory device can retain the stored data even when they are not powered. The flash memory device has been widely used as the storage media of portable electronic devices such as mobile phones, digital cameras, personal digital assistants (PDAs) and MP3 players. The flash memory device includes a plurality of memory cells that are adjacent to each other. Therefore, the inventor(s) has noted that interference and disturbance occur between the memory cells. Furthermore, the inventor(s) has noted that the memory cells connected to a word line closer to a drain selection line have more fail bits caused by program disturb. When the number of fail bits is greater than a reference number, the inventor(s) has experienced that a program operation is failed. The inventor(s) has experienced that the reliability of a semiconductor memory device is reduced for these reasons. The inventor(s) has experienced that a semiconductor memory device has high data reliability.

SUMMARY

In accordance with some embodiments, a semiconductor memory device comprises at least one cell string and a peripheral circuit. The at least one cell string includes a plurality of dummy memory cells and a plurality of memory cells con-

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nected in series between the plurality of dummy memory cells. And the peripheral circuit is configured to control the at least one cell string so that a first type of data represented by a first number of bits is stored in at least one of the dummy memory cells and a second type of data represented by a second number of bits, the second number smaller than the first number, is stored in at least two of the plurality of memory cells.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features and advantages will become readily apparent by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

FIG. 1 is a circuit diagram of interference caused by neighboring memory cells;

FIG. 2 is a view of the number of fail bits caused by a word-line program disturb;

FIG. 3 is a view of changes in threshold voltages of memory cells according to a program order;

FIG. 4 is a block diagram of a semiconductor memory device according to some embodiments;

FIG. 5 is a circuit diagram of a memory block of FIG. 4;

FIGS. 6 to 20 are views of a program method of a semiconductor memory device according to some embodiments;

FIG. 21 is a view of changes in threshold voltages of memory cells according to a program order when a method, illustrated in FIG. 6, is performed;

FIG. 22 is a view of the number of fail bits caused by a word-line program disturb when the method, illustrated in FIG. 6, is performed;

FIG. 23 is a schematic block diagram of a memory system according to some embodiments;

FIG. 24 is a schematic block diagram of a fusion memory device or a fusion memory system configured to perform a program operation according to some embodiments; and

FIG. 25 is a schematic block diagram of a computing system including a flash memory device according to some embodiments.

DESCRIPTION OF EMBODIMENTS

Hereinafter, various embodiments will be described with reference to the accompanying drawings. In the drawings, illustrated thicknesses and distances of components are exaggerated compared to an actual physical thickness and interval for convenience of illustration. In the following description, detailed explanation of known related functions and constitutions is omitted to avoid unnecessarily obscuring the subject matter disclosed herein. Like reference numerals refer to like elements throughout the specification and drawings.

FIG. 1 is a circuit diagram of interference caused by neighboring memory cells.

Referring to FIG. 1, a threshold voltage of a memory cell $M2n$, which is coupled to an n -th word line and a second bit line, is shifted due to interference caused by neighboring eighth memory cells, which is triggered by capacitance Cx between memory cells $M1n$ and $M3n$ adjacent to the memory cell $M2n$ in a word line direction, capacitance Cy between memory cells $M2n+1$ and $M2n-1$ adjacent to each other in a bit line direction, and capacitance Cz between memory cells $M1n+1$, $M3n+1$, $M1n-1$ and $M3n-1$ adjacent to each other in a diagonal direction.

FIG. 2 is a diagram of the number of fail bits caused by a word-line program disturb.

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In general, a program operation on memory cells is sequentially performed from a word line adjacent to a source selection line in a drain selection line direction. As memory cells of a word line are closer to a drain selection line, threshold voltages of the memory cells are shifted more in a positive direction due to interference between neighboring cells as described with reference to FIG. 1. In addition, since the memory cells of the word line closer to the drain selection line have greater source-side resistances, the memory cells are greatly affected by interference in a word line direction.

Referring to FIG. 2, memory cells of a word line closer to a drain selection line have more number of fail bits caused by program disturb. When the number of fail bits is greater than criterion, program fail occurs.

FIG. 3 is a diagram illustrating changes in threshold voltages of memory cells according to a program order.

Referring to FIG. 3, threshold voltage shift from an initial condition is not caused by interference until an LSB program operation is performed on memory cells connected to a word line $WLn-1$ (A). For example, threshold voltage shift of the memory cells is caused due to read disturb or pass disturb.

When an LSB program operation is performed on memory cells connected to the word line $WLn-1$ (B), threshold voltage shift of the memory cells is caused by pass disturb and interference in the word line direction and the diagonal direction.

When the LSB program operation is performed on memory cells connected to a word line WLn (C), threshold voltage shift of the memory cells is caused by program disturb and interference in the bit line direction.

When an MSB program operation is performed on memory cells connected to the word line $WLn-1$ (D), threshold voltage shift of the memory cells is caused by program disturb and additional interference in the word line direction as well as in the bit line direction.

When the MSB program operation is performed on memory cells connected to the word line WLn (E), threshold voltage shift of the memory cells is caused by program disturb and interference in the bit line direction.

When the MSB program operation is performed on memory cells connected to a word line $WLn+1$ (F), threshold voltage shift of the memory cells is caused by interference in the word line direction and the diagonal direction.

When twelve memory cells $M1$ to $M12$ are included in a single string and the memory cells $M12$ are adjacent to the drain selection line, a program operation is not performed after a program operation is performed on the memory cells $M12$ since there are no memory cells on which the program operation is subsequently performed between the memory cells $M12$ and the drain selection line. Therefore, a threshold voltage of the memory cells $M12$ is shifted less than the other memory cells $M1$ to $M11$. As a result, the number of fail bits caused by program disturb of the memory cells $M12$ is smaller than that of the other memory cells $M1$ to $M11$ (please refer to FIG. 2).

FIG. 4 is a circuit diagram of a semiconductor memory device according to some embodiments. FIG. 5 is a circuit diagram of a memory block illustrated in FIG. 4.

Referring to FIG. 4, a semiconductor memory device 100 according to some embodiments includes a memory array 110 and a peripheral circuit PERI. The memory array 110 includes first memory block $MB1$ to m -th memory block MBm . The peripheral circuit PERI is configured to perform a program operation and a verify operation on memory cells included in a selected page of the memory blocks $MB1$ to MBm .

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Referring to FIG. 5, each of the memory blocks includes strings $ST1$ to STk that are coupled between the bit lines $BL1$ to BLk and a common source line CSL. In other words, the strings $ST1$ to STk are coupled to the bit lines $BL1$ to BLk , respectively, and coupled in common to the common source line CSL. The string $ST1$ includes a source selection transistor SST having a source coupled to the common source line CSL, dummy memory cells $SDM1$ to $SDM3$ and $DDM1$ to $DDM3$, memory cells $M01$ to $Mn1$, and a drain selection transistor DST having a drain coupled to the bit line $BL1$. The memory cells $SDM3$ to $SDM1$, $M01$ to $Mn1$ and $DDM1$ to $DDM3$ are coupled in series between selection transistors SST and DST. A gate of the source selection transistor SST is coupled to the source selection line SSL. Gates of the dummy memory cells $SDM1$ to $SDM3$ and $DDM1$ to $DDM3$ are coupled to dummy word lines $SDWL1$ to $SDWL3$ and $DDWL1$ to $DDWL3$, respectively. Gates of the memory cells $M01$ to $Mn1$ are coupled to the word lines $WL0$ to WLn , respectively. A gate of the drain selection transistor DST is coupled to the drain selection line DSL.

Memory cells included in a memory block are divided into physical page units or logical page units. For example, memory cells $M01$ to $M0k$, which are coupled to a single word line, form a single physical page PAGE0. This page is a basic unit for a program operation.

The dummy memory cells $SDM1$ to $SDM3$ and $DDM1$ to $DDM3$ are divided into: (i) drain side dummy memory cells $DDM1$ to $DDM3$ between the memory cells $M01$ to $Mn1$ and the drain selection transistor DST; and (ii) source side dummy memory cells $SDM1$ to $SDM3$ between the memory cells $M01$ to $Mn1$ and the source selection transistor SST. FIG. 5 illustrates that both the drain side dummy memory cells $DDM1$ to $DDM3$ and the source side dummy memory cells $SDM1$ to $SDM3$ are included in the cell string $ST1$. However, the cell string $ST1$ includes only the drain side dummy memory cells $DDM1$ to $DDM3$ or the source side dummy memory cells $SDM1$ to $SDM3$. In addition, FIG. 5 illustrates that the cell string $ST1$ includes three drain side dummy memory cells $DDM1$ to $DDM3$ and three source side dummy memory cells $SDM1$ to $SDM3$. However, the above configuration is only illustrative, and the number of dummy memory cells is not limited thereto.

The memory cells $M01$ to $Mn1$ are configured to store a first type of data represented by a first number of bits. Although the dummy memory cells $SDM1$ to $SDM3$ and $DDM1$ to $DDM3$ have substantially the same configurations as the memory cells $M01$ to $Mn1$, the dummy memory cells $SDM1$ to $SDM3$ and $DDM1$ to $DDM3$ are configured not to store the data.

The peripheral circuit PERI includes a control circuit 120, a voltage supply circuit 130, a page buffer group 140, a column decoder 150 and an input/output circuit 160.

The control circuit 120 outputs a voltage control signal VCON in order to generate voltages necessary to perform a program operation or a verify operation in response to a command signal CMD, which is externally input through the input/output circuit 160, and outputs a page buffer (PB) control signal PBCON in order to control page buffers $PB1$ to PBk that are included in the page buffer group 140, depending on types of operations. In addition, the control circuit 120 outputs a row address signal RADD and a column address signal CADD in response to an address signal ADD, which is externally input through the input/output circuit 160. The control circuit 120 outputs the voltage control signal VCON and the row address signal RADD in order to store the first type of data represented by a first number of bits in at least one of the dummy memory cells $SDM1$ to $SDM3$ and $DDM1$ to

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DDM3 and store a second type of data represented by a second number of bits, which the second number is smaller than the first number, in at least two of the memory cells M01 to Mn1.

According to some embodiments, at least two memory cells are separated at regular intervals in the cell string ST1.

According to some embodiments, one of at least two memory cells is the second memory cell from the closest memory cell to the drain selection line in the source line direction, among the memory cells storing the first type of data.

According to some embodiments, one of at least two memory cells is the third memory cell from the closest memory cell to the drain selection line in the drain selection line, among the memory cells storing the first type of data.

The control circuit 120 outputs the voltage control signal VCON and the row address signal RADD in order to store the first type of data in at least one dummy memory cell and store the second type of data in at least two memory cells so that the total number of bits of data stored in the cell string ST1 are maintained. For example, when two-bit data is stored in one dummy memory cell, the control circuit 120 outputs the voltage control signal VCON and the row address signal RADD in order to store one-bit data in two memory cells. In addition, when the two-bit data is stored in two dummy memory cells, the control circuit 120 outputs the voltage control signal VCON and the row address signal RADD in order to store the one-bit data in four memory cells.

The voltage supply circuit 130 applies operating voltages for a program operation or a verify operation on the memory cells onto local lines, which include the drain selection line DSL, the dummy word lines SDWL1 to SDWL3 and DDWL1 to DDWL3, the word lines WL0 to WLn and the source selection line SSL, in response to the voltage control signal VCON of the control circuit 120 of a selected memory block. The voltage supply circuit 130 includes a voltage generation circuit and a row decoder.

The voltage generation circuit outputs operating voltages for a program operation or a verify operation on the memory cells to global lines in response to the voltage control signal VCON from the control circuit 120. For example, the voltage generation circuit outputs a program voltage to be applied to memory cells of a selected page and a pass voltage to be applied to unselected memory cells to the global lines in order to perform a program operation. The voltage generation circuit outputs a verify voltage to be applied to the memory cells of the selected page and a pass voltage to be applied to the unselected memory cells onto the global lines in order to perform a verify operation.

In response to the row address signals RADD from the control circuit 120, the row decoder couples the global lines and the local lines DSL, SDWL1 to SDWL3, DDWL1 to DDWL3, WL0 to WLn and SSL so that operating voltages, which are output onto the global lines from the voltage generation circuit, are transferred to the local lines DSL, SDWL1 to SDWL3, DDWL1 to DDWL3, WL0 to WLn and SSL of the selected memory block in the memory array 110. Therefore, the program voltage is applied to a local word line, coupled to a selected cell, from the voltage generation circuit to the global word line. In addition, the pass voltage is applied to local word lines coupled to unselected cells from the voltage generation circuit through the global word lines. Therefore, data is stored in the selected cell by the program voltage.

The page buffer group 140 includes the page buffers PB1 to PBk coupled to the memory array 110 through the bit lines BL1 to BLk, respectively. The page buffers PB1 to PBk of the page buffer group 140 selectively precharge the bit lines BL1

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to BLk on the basis of data being input in response to the PB control signal PBCON from the control circuit 120 so that the data are stored in the memory cells M01 to M0k.

The column decoder 150 selects the page buffers PB1 to PBk, included in the page buffer group 140, in response to the column address signal CADD which is output from the control circuit 120. In other words, the column decoder 150 sequentially transfers data to be stored in the memory cells to the page buffers PB1 to PBk in response to the column address signal CADD.

The input/output circuit 160 transfers externally input data to the column decoder 150 in response to control of the control circuit 120 in order to input the data to the page buffer group 140, so that the data are stored in the memory cells during a program operation. When the column decoder 150 transfers the data, transferred from the input/output circuit 160, to the page buffers PB1 to PBk of the page buffer group 140 in the same manner as described above, the page buffers PB1 to PBk store the input data in an internal latch circuit.

FIGS. 6 to 20 are diagrams illustrating a program method of a semiconductor memory device according to some embodiments. FIG. 21 is a diagram illustrating changes in threshold voltages of memory cells according to a program order when the method illustrated in FIG. 6 is performed. FIG. 22 is a diagram illustrating the number of fail bits caused by a word-line program disturb when the method illustrated in FIG. 6 is performed.

A description is made in reference to an example in which a single cell string includes three drain selection line-side dummy memory cells DDM1 to DDM3 (i.e., dummy memory cells DDM1 to DDM3 arranged at a direction of the drain selection line (DSL)), twelve memory cells M1 to M12 and three source selection line-side dummy memory cells SDM1 to SDM3 (i.e., dummy memory cells SDM1 to SDM3 arranged at a direction of the source selection line (SSL)). However, this exemplary embodiment is only illustrative, and the number of memory cells is not limited thereto. In addition, although a description is made in reference to an exemplary embodiment in which a two-bit data or one-bit data is stored in a memory cell, the number of bits is not limited thereto.

FIGS. 6 to 8 illustrate two-bit data is stored in the drain selection line-side dummy memory cell DDM1 and one-bit data, not the two-bit data, is stored in two memory cells.

Referring to FIG. 6, the two-bit data is stored in the drain selection line-side dummy memory cell DDM1. The one-bit data, not the two-bit data, is stored in the first memory cell M12, which is the second memory cell from a drain selection line-side in a source selection line direction, and the second memory cell M10, which is the fourth memory cell, among the memory cells (including DDM1) storing the two-bit data.

Referring to FIG. 21, since only the LSB program operation is performed on the adjacent memory cell M11, a final threshold voltage of the memory cell DDM1, which is the closest to a drain selection line, is reduced, and interference in the word line direction and the diagonal direction is reduced. Since the number of times a program operation is performed is reduced, pass disturb of an unselected word line adjacent to a selected word line is also reduced. As a result, threshold voltage shift caused by program disturb is reduced.

Since the MSB program operation is not performed on the first memory cell M10 and the second memory cell M12, stress caused by applying the program voltage is reduced. In addition, since threshold voltage shift caused by a program operation of a neighboring bit line is reduced, interference in the bit line direction is reduced. Threshold voltage shift caused by the program disturb is reduced the most.

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Since interference in the word line direction and the diagonal direction is reduced by the first and second memory cells M10 and M12, threshold voltage shift caused by program disturb of the memory cell M11 is reduced between the first and second memory cells M10 and M12.

Since interference in the word line direction and the diagonal direction, caused by the second memory cell M10, is reduced, threshold voltage shift caused by program disturb of the memory cell M9, adjacent to the second memory cell M10, is reduced.

FIG. 22 in accordance with at least one embodiment illustrates a reduction (a→b, i.e., a reduction in number of fail is incurred from curve 'a' to curve 'b') in number of fail bits caused by the five drain selection line-side memory cells M9 to M12 and DDM1.

Referring to FIG. 7, the two-bit data is stored in the drain selection line-side dummy memory cell DDM1. The one-bit data, rather than the second-bit data, is stored in the first memory cell M12, which is the second memory cell from the drain selection line-side in the source selection line direction, and the second memory cell M9, which is the fifth memory cell, among the memory cells (including DDM1) storing the two-bit data.

FIG. 6 illustrates a single memory cell storing two bits exists between memory cells storing one bit according to at least one embodiment. However, FIG. 7 illustrates two memory cells storing two bits exist between memory cells storing one bit. Therefore, threshold voltage shift of six drain selection line-side memory cells M8 to M12 and DDM1, caused by program disturb, is reduced.

Referring to FIG. 8, two-bit data is stored in the drain selection line-side dummy memory cell DDM1 (i.e., dummy memory cell DDM1 arranged at a direction of the drain selection line). One-bit data, not the two-bit data, is stored in the first memory cell M11, which is the third memory cell from the drain selection line-side in the source selection line direction, and the second memory cell M8, which is the sixth memory cell, among the memory cells (including DDM1) storing the two-bit data.

In this manner, interference in the word line direction and the diagonal direction of the memory cells M7, M9, M10, M12 and DDM1 is reduced. Threshold voltage shift caused by program disturb of the seven drain selection line-side memory cells M7 to M12 and DDM1 is reduced.

As described above, two-bit data is stored in one of the drain selection line-side dummy memory cells, and one-bit data, rather than the first two-bit data, is stored in two memory cells, so that threshold voltage shift of a memory cell to be programmed is reduced while the total number of bits of data to be stored is maintained. In addition, since stress caused by applying a program voltage is reduced, threshold voltage shift caused by program disturb is reduced. Also, since the number of ISPP loops being performed is reduced, threshold voltage shift caused by pass disturb of an unselected word line adjacent to a selected word line is reduced. Therefore, a plurality of memory cells have improved program disturb characteristics.

FIGS. 9 to 11 illustrate two-bit data is stored in the source selection line-side dummy memory cell SDM1 and one-bit data, not the two-bit data, is stored in two memory cells.

Referring to FIG. 9, the two-bit data is stored in the source selection line-side dummy memory cell SDM1. The one-bit data, not the two-bit data, is stored in the first memory cell M11, which is the second memory cell from the drain selection line-side in the source selection line direction, and the second memory cell M9, which is the fourth memory cell, among the memory cells (including SDM1) storing the two-

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bit data. In substantially the same manner as illustrated in FIG. 6, threshold voltage shift caused by program disturb of the five drain selection line-side memory cells M8 to M12 is reduced.

Referring to FIG. 10, the two-bit data is stored in the source selection line-side dummy memory cell SDM1. The one-bit data, not the two-bit data, is stored in the first memory cell M11, which is the second memory cell from the drain selection line-side in the source selection line direction, and the second memory cell M8, which is the fifth memory cell, among the memory cells (including SDM1) storing the two-bit data. In substantially the same manner as illustrated in FIG. 7, threshold voltage shift caused by program disturb of the six drain selection line-side memory cells M7 to M12 is reduced.

Referring to FIG. 11, the two-bit data is stored in the source selection line-side dummy memory cell SDM1. The one-bit data, not the two-bit data, is stored in the first memory cell M10, which is the third memory cell from the drain selection line-side in the source selection line direction, and the second memory cell M7, which is the sixth memory cell, among the memory cells (including SDM1) storing the two-bit data. In substantially the same manner as illustrated in FIG. 8, interference in the word line direction and the diagonal direction of the memory cells M6, M8, M9, M11 and M12 is reduced. Threshold voltage shift caused by program disturb of the seven drain selection line-side memory cells M6 to M12 is reduced.

FIGS. 12 to 14 illustrate two-bit data is stored in the drain selection line-side dummy memory cell DDM1 and the source selection line-side dummy memory cell SDM1 and one-bit data, not the two-bit data, is stored in four memory cells.

Referring to FIG. 12, the two-bit data is stored in the drain selection line-side dummy memory cell DDM1 and the source selection line-side dummy memory cell SDM1. The one-bit data, not the two-bit data, is stored in the memory cell M12, which is the second memory cell from the drain selection line-side in the source selection line direction, the memory cell M10, which is the fourth memory cell, the memory cell M8, which is the sixth memory cell, and the memory cell M6, which is the eighth memory cell, among the memory cells (including DDM1 and SDM1) storing the two-bit data. In this manner, threshold voltage shift caused by program disturb of the nine memory cells M5 to M12 and DDM1 is reduced.

Referring to FIG. 13, the two-bit data is stored in the drain selection line-side dummy memory cell DDM1 and the source selection line-side dummy memory cell SDM1. The one-bit data, not the two-bit data, is stored in the memory cell M12, which is the second memory cell from the drain selection line-side in the source selection line direction, the memory cell M9, which is the fifth memory cell, the memory cell M6, which is the eighth memory cell, and the memory cell M3, which is the eleventh memory cell, among the memory cells (including DDM1 and SDM1) storing the two-bit data. In this manner, threshold voltage shift caused by program disturb of the twelve drain selection line-side memory cells M2 to M12 and DDM1 is reduced.

Referring to FIG. 14, the two-bit data is stored in the drain selection line-side dummy memory cell DDM1 and the source selection line-side dummy memory cell SDM1. The one-bit data, not the two-bit data, is stored in the memory cell M11, which is the third memory cell from the drain selection line-side in the source selection line direction, the memory cell M8, which is the sixth memory cell, the memory cell M5, which is the ninth memory cell, and the memory cell M2,

which is the twelfth memory cell, among the memory cells (including DDM1 and SDM1) storing the two-bit data. In this manner, threshold voltage shift caused by program disturb of the thirteen drain selection line-side memory cells M1 to M12 and DDM1 is reduced.

FIGS. 15 and 16 illustrate two-bit data is stored in the drain selection line-side dummy memory cell DDM2, one-bit data is stored in the drain selection line-side dummy memory cell DDM1 and one-bit data, not the two-bit data, is stored in three memory cells.

Referring to FIG. 15, the two-bit data is stored in the drain selection line-side dummy memory cell DDM2, and the one-bit data is stored in the drain selection line-side dummy memory cell DDM1. The one-bit data, not the two-bit data, is stored in the memory cell M11, which is the fourth memory cell from the drain selection line-side in the source selection line direction, the memory cell M9, which is the sixth memory cell, and the memory cell M7, which is the eighth memory cell, among the memory cells (including DDM2) storing the two-bit data. In this manner, threshold voltage shift caused by program disturb of the nine drain selection line-side memory cells M6 to M12, DDM1 and DDM2 is reduced.

Referring to FIG. 16, the two-bit data is stored in the drain selection line-side dummy memory cell DDM2. The one-bit data is stored in the drain selection line-side dummy memory cell DDM1. The one-bit data, not the two-bit data, is stored in the second memory cell M10, which is the fifth memory cell from the drain selection line-side in the source selection line direction, the memory cell M7, which is the eighth memory cell, and the memory cell M4, which is the eleventh memory cell, among the memory cells (including DDM2) storing the two-bit data. In this manner, threshold voltage shift caused by program disturb of the twelve drain selection line-side memory cells M3 to M12, DDM1 and DDM2 is reduced.

FIG. 17 illustrates two-bit data is stored in two drain selection line-side dummy memory cells DDM2 and DDM1 and one-bit data, not the two-bit data, is stored in four memory cells.

Referring to FIG. 17, the two-bit data is stored in the drain selection line-side dummy memory cells DDM1 and DDM2. The one-bit data, not the two-bit data, is stored in the memory cell M12, which is the third memory cell from the drain selection line-side in the source selection line direction, the memory cell M9, which is the sixth memory cell, the memory cell M6, which is the ninth memory cell, and the memory cell M3, which is the twelfth memory cell, among the memory cells (including DDM2 and DDM1) storing the two-bit data. In this manner, threshold voltage shift caused by program disturb of the thirteen drain selection line-side memory cells M2 to M12, DDM1 and DDM2 is reduced.

FIGS. 18 to 20 illustrate two-bit data is stored in two source selection line-side dummy memory cell SDM1 and SDM2 and one-bit data, not the two-bit data, is stored in four memory cells.

Referring to FIG. 18, the two-bit data is stored in the source selection line-side dummy memory cells SDM1 and SDM2. The one-bit data, not the two-bit data, is stored in the memory cell M11, which is the second memory cell from the drain selection line-side in the source selection line direction, the memory cell M9, which is the fourth memory cell, the memory cell M7, which is the sixth memory cell, and the memory cell M5, which is the eighth memory cell, among the memory cells (including SDM1 and SDM2) storing the two-bit data. In this manner, threshold voltage shift caused by program disturb of the nine drain selection line-side memory cells M4 to M12 is reduced.

Referring to FIG. 19, the two-bit data is stored in the source selection line-side dummy memory cells SDM1 and SDM2. The one-bit data, not the two-bit data, is stored in the memory cell M11, which is the second memory cell from the drain selection line-side in the source selection line direction, the memory cell M8, which is the fifth memory cell, the memory cell M5, which is the eighth memory cell, and the memory cell M2, which is the eleventh memory cell, among the memory cells (including SDM1 and SDM2) storing two-bit data. In this manner, threshold voltage shift caused by program disturb of the twelve drain selection line-side memory cells M1 to M12 is reduced.

Referring to FIG. 20, the two-bit data is stored in the source selection line-side dummy memory cells SDM1 and SDM2. The one-bit data, not the two-bit data, is stored in the memory cell M10, which is the third memory cell from the drain selection line-side in the source selection line direction, the memory cell M7, which is the sixth memory cell, the memory cell M4, which is the ninth memory cell, and the memory cell M1, which is the eleventh memory cell, among the memory cells (including SDM1 and SDM2) storing the two-bit data. Threshold voltage shift caused by program disturb of the thirteen drain selection line-side memory cells SDM1 and M1 to M12 is reduced.

FIG. 23 is a schematic block diagram of a memory system according to at least one embodiment of the present invention.

Referring to FIG. 23, a memory system 600 according to some embodiments includes a memory controller 610 and a non-volatile memory device 620.

The non-volatile memory device 620 is configured into the above-described semiconductor memory device and operated by the above-described method for compatibility with the memory controller 610. The memory controller 610 is configured to control the non-volatile memory device 620. The memory system 600 having the above-described configuration is a memory card or a solid state disk (SSD) in which the non-volatile memory device 620 and the memory controller 610 are combined. SRAM 611 is configured to function as an operation memory of a CPU 612. A host interface 613 includes a data exchange protocol of a host being coupled to the memory system 600. An ECC 614 is configured to detect and correct errors included in a data read from the non-volatile memory device 620. A memory interface 615 is configured to interface with the non-volatile memory device 620. The CPU 612 is configured to perform the general control operation for data exchange of the memory controller 610.

Though not illustrated in FIG. 23, the memory system 600 further includes ROM (not illustrated) that stores code data to interface with the host. In addition, the non-volatile memory device 620 is a multi-chip package having a plurality of flash memory chips. The memory system 600 is provided as a storage medium having high reliability and low error rate. A flash memory device according to some embodiments is provided in a memory system such as a semiconductor disk device (a solid state disk (SSD)) on which research has been actively conducted. For example, when the memory system 600 is an SSD, the memory controller 610 communicates with an external device (e.g., a host) through one of the interface protocols including USB, MMC, PCI-E, SATA, PATA, SCSI, ESDI and IDE.

FIG. 24 is a schematic block diagram of a fusion memory device or a fusion memory system that performs a program operation according to the aforementioned various embodiments. For example, technical features of the present disclosure are applied to a OneNand flash memory device 700 as the fusion memory device.

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The OneNand flash memory device **700** includes a host interface (I/F) **710**, a buffer RAM **720**, a controller **730**, a register **740** and a NAND flash cell array **750**. The host interface **710** is configured to exchange various types of information with a device through a different protocol. The buffer RAM **720** has built-in codes for driving the memory device or temporarily stores data. The controller **730** is configured to control read and program operations and every state in response to a control signal and a command that are externally given. The register **740** is configured to store data including instructions, addresses and configurations defining a system operating environment in the memory device. The NAND flash cell array **750** includes operating circuits including non-volatile memory cells and page buffers. In response to a write request from a host, the OneNAND flash memory device **700** programs data in the aforementioned manner.

FIG. **25** is a schematic block diagram of a computing system including a flash memory device **812** according to some embodiments.

A computing system **800** according to some embodiments includes a microprocessor (CPU) **820**, random-access memory (RAM) **830**, a user interface **840**, a modem **850**, such as a baseband chipset, and a memory system **810** that are electrically coupled to a system bus **860**. In addition, if the computing system **800** is a mobile device, then a battery is additionally provided to apply operating voltages to the computing system **800**. Though not shown in FIG. **8**, the computing system **800** further includes application chipsets, a Camera Image Processor (CIS), or mobile DRAM. The memory system **810** forms a Solid State Drive/Disk (SSD) that uses a non-volatile memory to store data. The memory system **810** is provided as a fusion flash memory (e.g., OneNAND flash memory).

According to some embodiments, since a semiconductor memory device prevents fail caused by program disturb, the semiconductor memory device has increased data reliability.

In addition, yield and program performance is improved.

Various embodiments described above are not limited to a device and a method but is implemented through a program implementing functions corresponding to the features of embodiments or a non-transitory, computer-readable recording medium where the program is recorded. Such implementation is easily done by a person of ordinary skill in the art based on the description of the embodiments.

Example embodiments have been disclosed herein, and although specific terms are employed, they are used and are to be interpreted in a generic and descriptive sense only and not for purpose of limitation. In some instances, as would be apparent to one of ordinary skill in the art as of the filing of the present application, features, characteristics, and/or elements described in connection with a particular embodiment are used singly or in combination with features, characteristics, and/or elements described in connection with other embodiments unless otherwise specifically indicated. Although embodiments have been described with reference to a number of illustrative embodiments thereof, it should be understood that numerous other modifications and various embodiments can be devised by those skilled in the art that will fall within the spirit and scope of the claimed invention as set forth in the following claims.

What is claimed is:

1. A semiconductor memory device, comprising:
at least one cell string including a plurality of dummy memory cells and a plurality of memory cells connected in series between the plurality of dummy memory cells;
and

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a peripheral circuit configured to store a first type of data represented by a first number of bits in at least one of the dummy memory cells, and store a second type of data represented by a second number of bits in at least two of the plurality of memory cells, wherein the second number is smaller than the first number.

2. The semiconductor memory device of claim 1, wherein the at least two memory cells of the plurality of memory cells are separated at regular distances in the at least one cell string.

3. The semiconductor memory device of claim 2, wherein one of the at least two memory cells is a second outermost memory cell, among the memory cells storing the second type of data.

4. The semiconductor memory device of claim 2, wherein one of the at least two memory cells is a third outermost memory cell, among the memory cells storing the first type of data.

5. The semiconductor memory device of claim 1, wherein the peripheral circuit is configured to store the first type of data in the at least one dummy memory cell and store the second type of data in the at least two memory cells in order to maintain a total number of bits of data stored in the at least one cell string.

6. The semiconductor memory device of claim 5, wherein the first type of data is two bits, and the second type of data is one bit, and

the peripheral circuit is configured to store the second type of data in two memory cells when the first type of data is stored in a single dummy memory cell.

7. The semiconductor memory device of claim 6, wherein the single dummy memory cell is adjacent to a first memory cell of the plurality of memory cells or an n-th memory cell of the plurality of memory cells, where $n > 1$, n is a natural number, and n is the number of the memory cells in the least one cell string.

8. The semiconductor memory device of claim 5, wherein the first type of data is two bits, and the second type of data is one bit, and

the peripheral circuit is configured to store the second type of data in four memory cells when the first type of data is stored in two dummy memory cells.

9. The semiconductor memory device of claim 8, wherein one of the two dummy memory cells is adjacent to a first memory cell of the plurality of memory cells, and the other is adjacent to an n-th memory cell of the plurality of memory cells, where $n > 1$, n is a natural number, and n is the number of the memory cells in the least one cell string.

10. The semiconductor memory device of claim 8, wherein a first dummy memory cell of the two dummy memory cells is adjacent to the first memory cell of the plurality of memory cells, and a second dummy memory cell is adjacent to the first dummy memory cell.

11. The semiconductor memory device of claim 8, wherein the two dummy memory cells include

a first dummy memory cell adjacent to an n-th memory cell of the plurality of memory cells, where $n > 1$, n is a natural number and n is the number of the memory cells in the least one cell string and

a second dummy memory cell is adjacent to the first dummy memory cell.

12. The semiconductor memory device of claim 1, wherein the peripheral circuit is configured to control the at least one cell string so that

the first type of data is stored in a dummy memory cell adjacent to an n-th memory cell of the plurality of memory cells, among the dummy memory cells, and

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the second type of data is stored in an n -th memory cell and an $(n-2)$ -th memory cell of the plurality of memory cells where $n > 1$, n is a natural number, and n is the number of the memory cells in the least one cell string.

13. The semiconductor memory device of claim 1, wherein the peripheral circuit is configured to control the at least one cell string so that

the first type of data is stored in a dummy memory cell adjacent to an n -th memory cell of the plurality of memory cells, among the dummy memory cells, and the second type of data is stored in an n -th memory cell and an $(n-3)$ -th memory cell of the plurality of memory cells, where $n > 1$, n is a natural number, and n is the number of the memory cells in the least one cell string.

14. The semiconductor memory device of claim 1, wherein the peripheral circuit is configured to control the at least one cell string so that

the first type of data is stored in a dummy memory cell adjacent to an n -th memory cell of the plurality of memory cells, among the dummy memory cells, and the second type of data is stored in an $(n-1)$ -th memory cell and an $(n-4)$ -th memory cell of the plurality of memory cells, where $n > 1$, n is a natural number, and n is the number of the memory cells in the least one cell string.

15. The semiconductor memory device of claim 1, wherein the peripheral circuit is configured to control the at least one cell string so that

the first type of data is stored in a dummy memory cell adjacent to a first memory cell of the plurality of memory cells, among the dummy memory cells, and the second type of data is stored in an $(n-2)$ -th memory cell and an $(n-5)$ -th memory cell of the plurality of memory cells, where $n > 1$, n is a natural number, and n is the number of the memory cells in the least one cell string.

16. The semiconductor memory device of claim 1, wherein the peripheral circuit is configured to control the at least one cell string so that

the first type of data is stored in a dummy memory cell adjacent to an n -th memory cell of the plurality of memory cells and a dummy memory cell adjacent to a first memory cell of the plurality of memory cells, among the dummy memory cells, and

the second type of data is stored in an n -th memory cell, an $(n-2)$ -th memory cell, an $(n-4)$ -th memory cell and an $(n-6)$ -th memory cell of the plurality of memory cells, where $n > 1$, n is a natural number, and n is the number of the memory cells in the least one cell string.

17. The semiconductor memory device of claim 1, wherein the peripheral circuit is configured to control the at least one cell string so that

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the first type of data is stored in a dummy memory cell adjacent to an n -th memory cell of the plurality of memory cells and a dummy memory cell adjacent to a first memory cell of the plurality of memory cells, among the dummy memory cells, and

the second type of data is stored in an $n-1$ -th memory cell, an $n-4$ -th memory cell, an $n-7$ -th memory cell and an $n-10$ -th memory cell of the plurality of memory cells, where $n > 1$, n is a natural number, and n is the number of the memory cells in the least one cell string.

18. The semiconductor memory device of claim 1, wherein the peripheral circuit is configured to control the at least one cell string so that

the first type of data is stored in a first dummy memory cell adjacent to a first memory cell of the plurality of memory cells and a second dummy memory cell adjacent to the first dummy memory cell, among the dummy memory cells, and

the second type of data is stored in an $n-2$ -th memory cell, an $n-5$ -th memory cell, an $n-8$ -th memory cell and an $n-11$ -th memory cell of the plurality of memory cells, where $n > 1$, n is a natural number, and n is the number of the memory cells in the least one cell string.

19. The semiconductor memory device of claim 1, wherein the peripheral circuit is configured to control the at least one cell string so that

the second type of data is stored in a first dummy memory cell adjacent to an n -th memory cell, an $n-1$ -th memory cell, an $n-3$ -th memory cell and an $n-5$ -th memory cell of the plurality of memory cells, among the dummy memory cells, and

the first type of data is stored in a second dummy memory cell adjacent to the first dummy memory cell where $n > 1$, n is a natural number, and n is the number of the memory cells in the least one cell string.

20. The semiconductor memory device of claim 1, wherein the peripheral circuit is configured to control the at least one cell string so that

the first type of data is stored in a first dummy memory cell adjacent to an n -th memory cell of the plurality of memory cells and a second dummy memory cell adjacent to the first dummy memory cell, among the dummy memory cells, and

the second type of data is stored in an n -th memory cell, an $n-3$ -th memory cell, an $n-6$ -th memory cell and an $n-9$ -th memory cell of the plurality of memory cells, where $n > 1$, n is a natural number, and n is the number of the memory cells in the least one cell string.

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